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STUDY ON THE MECHANICAL PROPERTIES OF THE FLY ASH GEOPOLYMER CONCRETE

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ABSTRACT

This paper presents the results of the research on the mechanical characteristics of fly ash geopolymer concrete (GPC). Three mixture of geopolymer concrete graded 30, 40 and 50 MPa were prepared. The process of experimental studies that is used to determine the compressive strength, modulus of elasticity, flexural strength is performed in accordance with ASTM standards. The results are analysed and evaluated according to statistical methods. The value of modulus of elasticity and characteristic bending tensile strength of geopolymer concrete will be compared with the value of the equivalent cement concrete that are calculated according to the prevailing theory. The evaluation of the mechanical properties of the fly ash geopolymer concrete is needed for the research and application of this material in the construction.

Key words: Geopolymer, fly ash, strength.

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1. INTRODUCTION

Geopolymer is an inorganic polymer bonding, developed firstly by French scientist, Joseph Davidovits, in the 1970s. Geopolymerization is a chemical reaction between aluminum oxide and silicon oxide. Highly alkaline solution will create solid three-dimensional structures of Si-O-Al [15]. The process of geopolymerization can be shown in Figure 1 [11]. The geopolymerization reaction takes place in atmospheric pressure and below 100°C [10]. The

final product will be characterized by many factors related to the chemical composition of activated materials and alkaline solutions.

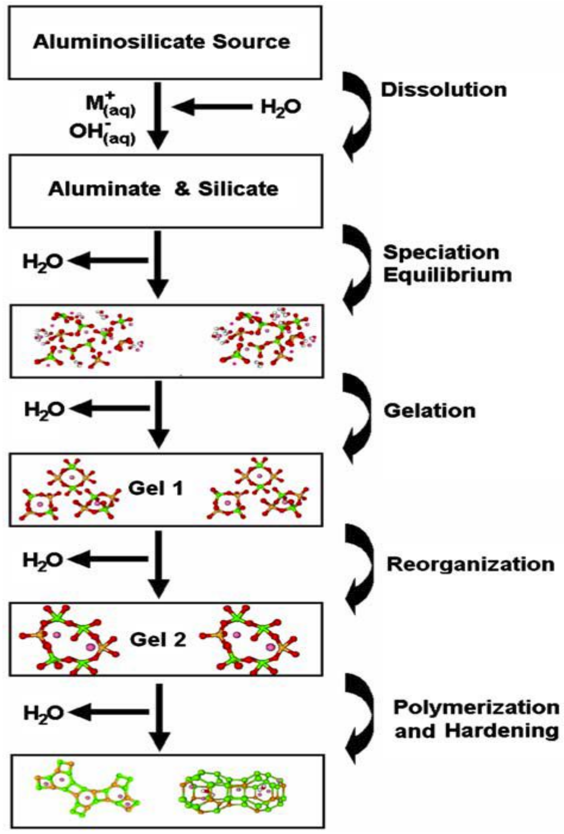

Figure 1 Conceptual model for geopolymerization [11]

Materials rich of aluminum and silica in geopolymerisation are industrial wastes such as fly ash, steel slag, blast furnace slag ... In specific, fly ash is the most suitable material for both its size and chemical composition.

Fly ash geopolymer concrete has been studied and used for civil, including road and airport construction works in Australia for the past 10 years but in other countries, this material usage in construction is limited.

To apply fly ash geopolymer concrete in structure, the evaluation of its mechanical properties is necessary. The mechanical properties are tested and assessed include compressive strength, elastic modulus, tensile bending strength. Results of researches will be the basis for this material development in the field of construction in the coming time.

2. MATERIALS & EXPERIMENTAL PROCEDURES

2.1. Materials

2.1.1. Coarse Aggregate

Coarse aggregate concrete used for the experiment is quarry rubble of diameter D_{max} = 25mm. It is sieved into size group by particle size sieves and mixed to satisfy particle sizes in compliance with ASTM C136-01 [7] as seen in Figure 2 and Figure 3 below.

Figure 2 Particle size of aggregate after sieved according to ASTM C136-01 [7]

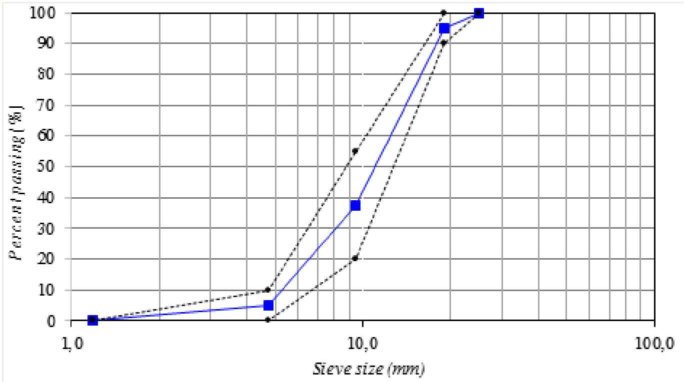

Figure 3 Grading of coarse aggregate according to ASTM C136-01 [7]

2.1.2. Fine Aggregate

Fine aggregate used for experiments is river sand. The particle size larger than 5 mm is removed by sieving in the lab. Sand has particle modules M_k = 2.55 which meets the requirements of ASTM C136-01 [4]. Figure 4 below is described the grading of sand.

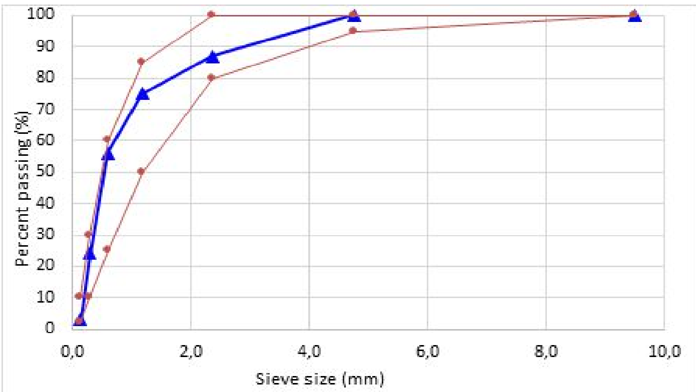

Figure 4 Grading of fine aggregate according to ASTM C136-01 [7]

2.1.3. Fly Ash (FA)

Fly ash in the experiment is supplied by the factory Vina F & C fly ash origin from Thermal Power Plant, Pha Lai. Test results of chemical composition of fly ash provided by the Institute of Building Materials are presented in Table 1 below. This is similar to fly ash type F in ASTM C618-03 [9].

Table 1 Chemical composition of fly ash used in the study (% by weight)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	SO_3	Weight loss by heating
54.42	23.90	8.14	2.56	1.74	1.77	0.43	1.32	0.78	4.31

2.1.4. Alkaline Activator Solution (AAS)

Activated alkaline solution is a mixture of Sodium solution (NaOH) and Sodium Silicate or glass liquid (Na_2SiO_3). Sodium solution is prepared from dry flake NaOH (98% purity) mixing with water to achieve the required molar concentration. Glass liquid is supplied by Viet Tri chemical company with ratio of $Na_2O/SiO_2/H_2O$ was 11.8/28.5/59.7% by weight respectively. Mixing proportion (Na_2SiO_3/NaOH) was 2.5 [13].

2.2. Component Proportion of Fly Ash Geopolymer

Component proportion of fly ash geopolymer used in testing is presented in Table 2 [1]:

Table 2 Proportion for 1m^3 mixture of GPC grade 30, 40, and 50 Mpa (Kg) [1]

Compositions of GPC		G 30	G40	G50
Fly ash		372.52	375.84	390.35
Coarse aggregate (crushed stone)	2.36-4.75 mm	64.68	64.68	64.68
	4.75-9.50 mm	420.42	420.42	420.42
	9.50-19.0 mm	743.82	743.82	743.82
	19.0-25.0 mm	65.68	65.68	65.68
Fine aggregate (Sand)		554.0	554.0	554.0
Solution NaOH		51.28 (12 M)	50.33 (14 M)	46.18 (16 M)
Solution Na_2SiO_3		128.20	125.83	115.46
Na_2SiO_3/NaOH (by mass)		2.5	2.5	2.5
AAS/FA (by mass)		0.4818	0.4687	0.4141
Specimens were cured at 60^{o}C in 24 hours				

2.3. Testing Plan

With 30 cylindrical samples of 15x30 cm were used to verify the compressive strength and elastic modulus, 18 prisms of 15x15x60 cm to find out flexural strength**, c**orresponding to each GPC mixture. Determining compressive strength by C39-01 [5], tensile flexural strength by ASTM C78-02 [6], elastic modulus by ASTM C469-02 [8]

2.4. Testing Procedure

Fly ash geopolymer concrete can be created by applying conventional technology like cement concrete. After casting for 2 days, the samples are removed and placed in a drying chamber at 60^{o}C/24 hours. Select temperature of 60°C to ensure the best performance in both the intensity and energy categories [16]. After thermal treatment, samples are stored in the laboratory for 28 days of age (Figure 5) and laboratory tests were performed to determine mechanical properties (Figure 6).

Figure 5 Samples in laboratory

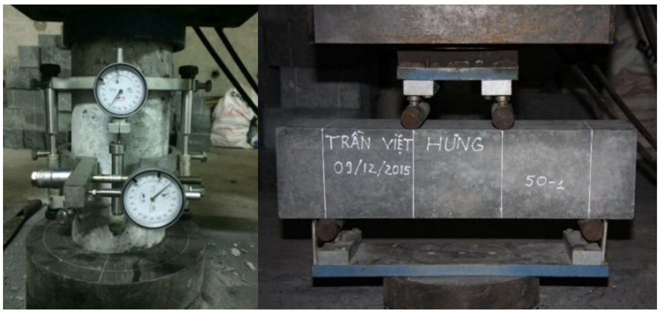

Figure 6 Testing of GPC elastic modulus and tensile flexural strength

3. RESULT AND DICUSSION

3.1. Testing Result

After got the testing results of each test sample, statistical analysis and evaluation of the results with a 99% assurance probability are conducted in accordance with ACI 214.R-02 [2]. The results of experiments to find the compressive strength, elastic modulus and tensile flexure strength of the samples were presented in Table 3 as follows:

Table 3 Experimental results determine the mechanical properties of GPC

Items	Mix GPC	Total sample	Average (Mpa)	Standard deviation S (Mpa)	Variancecoefficient C_v (%)	Specific value (Mpa)
Compressive strength	G_30	30	39,46	3,34	8,48	31,68
	G_40	30	49,86	4,03	8,09	40,46
	G_50	30	59,81	3,33	5,56	52,07
Elastic modulus	G_30	30	30424	2305	7,58	25061
	G_40	30	31497	2197	6,97	26387
	G_50	30	33650	2790	8,29	27159
Tensile flexure strength	G_30	18	4,93	0,49	9,88	3,79
	G_40	18	6,29	0,50	7,98	5,02
	G_50	18	7,13	0,53	7,38	5,80

3.2. Elastic Modulus

From the elastic modulus result test, the authors develop a relationship chart between the elastic modulus and the specific compressive strength. The results of GPC are compared with

the modulus of elasticity of the OPC by ACI 363-11 [4], AASHTO 2012 [14], and by Hardjito et al. experiment formula for fly ash geopolymer concrete [12].

- The proposed formula of the American Concrete Institute, ACI 363 -11 [4]:

$$E_c = 3320\sqrt{f_c^{'}} + 6900 \text{ (MPa)} \quad (1)$$

- The formula from AASHTO 2012 [14]:

$$E_c = 0,043\rho^{1,5}\sqrt{f_c^{'}} \quad \text{(MPa)} \quad (2)$$

- Hardjito et al's experiment formula for fly ash geopolymer concrete [12]:

$$E_c = 2707\sqrt{f_c^{'}} + 5300 \text{ (MPa)} \quad (3)$$

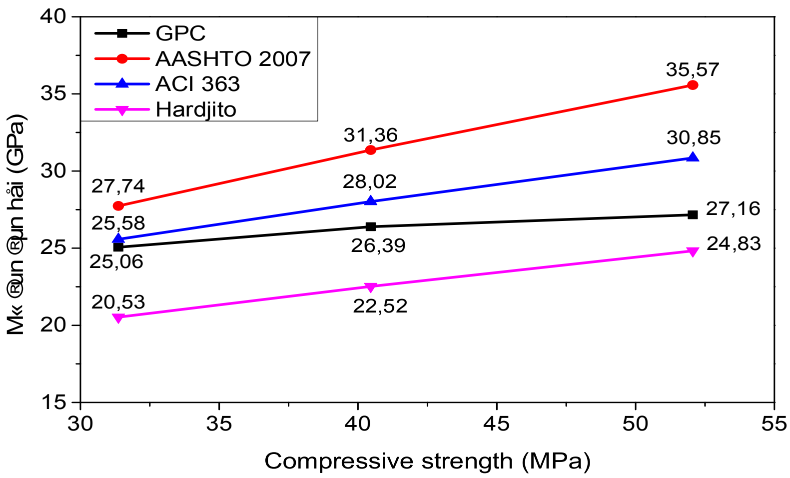

Figure 7 Elastic modulus of GPC

The results in Figure 7 describe that the elastic modulus of fly ash geopolymer concrete is less valuable than the modulus of elasticity of OPC at the same level from calculated by ACI 363-11 between 2-14% and much lower than the AASHTO 2012 calculation of 10-30%. The main cause is that GPC uses a fly ash geopolymer mix as a completely different cement concrete. As the intensity of the GPC increases, the difference is more. However, the value of elastic modulus of GPC was higher than elastic modulus of GPC create in Australia by Hardjito's [12]. This may be due to the composition of the substances in the fly ash binder, from the elastic modulus of the original stone and different aggregates. This result shows that GPC has lower elastic modulus than OPC, which leads to the possibility of deformation when subjected to the load, in turn GPC greater than that of OPC with the same compressive strength.

3.3. Tensile Flexure Strength

The testing results to determine the tensile flexure strength of GPC are compared with the flexure strength of concrete on the same grade as specified in the American Concrete Institute ACI 318-11 [3].

Formula for determining the tensile flexure strength of OPC concrete in accordance with ACI318-11 [3]:

$$f_r = 0,63.\sqrt{f_c^{'}} \text{ (MPa)} \quad (4)$$

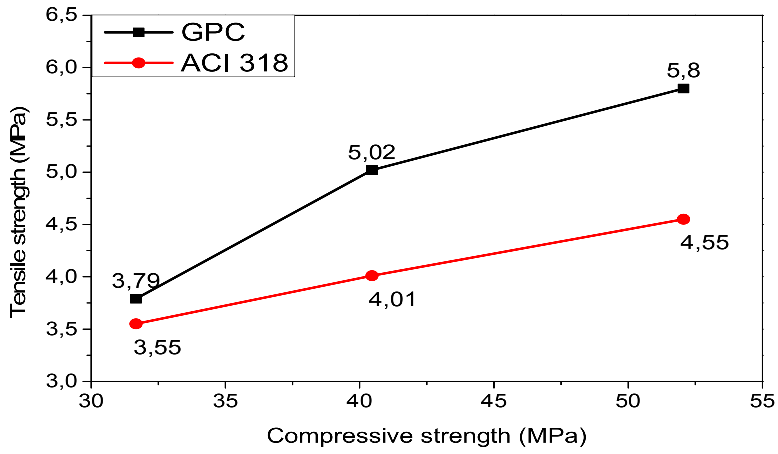

Figure 8 Tensile flexure strength of GPC

The results in Figure 8 show that the tensile strength of GPC is much greater than the calculated for cement concrete on the same compressive strength. This value is greater than the range from 1.07 to 1.27 times. This shows that the advantage of GPC more than OPC. The high tensile flexure strength reduces the cracks in the concrete, reducing the rebar of the tensile zone of the tensile flexural structure.

4. CONCLUSION

From the testing results in this study, the conclusions and recommendations can be drawn:

- Fly ash geopolymer concrete is molded and maintained in laboratory conditions has low dispersion in the test results
- With the same strengths of 30-50 MPa, compared with OPC, GPC's elastic modulus is lower than OPC is that calculated for cementitious standards, due to differences of binder in the cement concrete.
- The tensile flexue strength of GPC is higher than 7-27% that calculated by ACI 318-11.
- Mechanical characteristics of GPC are important in orientingGPC research in the construction sector.

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